El Nino manifestations in Southern Peru: modern observations, documentary historical data and reconstruction of Holocene events

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The reconstruction of the occurrences of former El Niño events in the geological record and of their variation through time in frequency and intensity are topics of major importance in ENSO studies. Understanding the interactions between ENSO and other modes of climate variability ranges requires an accurate knowledge regarding the onset of the modern modality of ENSO, boundary conditions of the El Niño system, chronological series of past events in the last centuries/millennia, variation of intensity of individual events, etc.. This kind of information, deeply needed in climate modeling studies oriented towards forecast and mitigation of future events, is being sought in a number of high-resolution records like lacustrine and marine deposits, coral and ice cores, seashells, speleothems, debris flows and tree-rings. Such research activities are carried on in many places, including Peru.

One of the earliest work dedicated to the reconstruction of a chronological series of El Niño event occurrences was that of Quinn et al. (1987). This pioneer paper which also proposed an intensity scale of the events (i.e.: weak, moderate, strong and very strong) was based upon documentary data compiled from published sources dealing with reports of anomalous rainfalls and storm events on the coast of Peru, travel time of ships in the eastern Pacific, or anomalous SST and air-temperature episodes in western South America. Later, Quinn and Neal (1992) and Quinn (1993) refined this 4 ½ century-long chronology by including additional documentary data, mainly from other countries than Peru (Chile, Bolivia and Brasil). In 1992, Hocquenghem & Ortlieb (1992) began to quote and comment the sources cited by Quinn and co-authors (but not reproduced by them). This led the last authors to question the occurrence of some of the reconstructed events (1525-1900), or the inferred intensity of some other events. Among the discrepancies can be mentioned a series of historical cases for which the only reports used by Quinn and co-authors were dealing with Rimac River floods, or isolated thunderstorms, or abundant rainfalls in the southern Andes or on the coast of southern Peru. More recently, Ortlieb (1999, 2000) updated the Quinn's chronology, by completing the revision of all the available documentary sources which deal with climatic anomalies during the sixteenth-nineteenth centuries in Peru and southern Ecuador. In this documentary approach has been addressed the problem of the validation of El Niño proxies, in terms of geographical distribution of the impacts and of paleo-intensity of the events. In some cases, the available documentary data on climatic anomalies in Southern Peru contradicts the reconstruction of El Niño events (e.g. no coeval, typical ENSO anomalies in northern Peru), and in many other cases documentary data from the southern Peru region does not appear as relevant for former event reconstructions. In some historical cases, anomalous vegetation blooms reported from the southern coast of Peru seem to have been related to anomalously wet winter seasons (« Lomas » weather) that may reflect La Niña events.

As shown by several recent studies on the impacts of El Niño events during the last few decades and the distribution of rainfall anomalies (Minaya, 1994; Rome-Gaspaldy & Ronchail, 1999; Rossel 1997; Evans et al., 1998), only the northern coastal region of Peru (and southwestern-most Ecuador) is recording a clear-cut positive correlation. During warm ENSO events, the southern coast of Peru and the southern Peru Andes may either suffer drought episodes (like in 1982-83) or precipitation excess (like in 1953, 1957, 1972, 1997-98). In the last 40 years, precipitation excess were thus recorded at Tacna during El Niño events, but stronger rainfall than the mean were also recorded in non-El Niño years (including La Niña events) (1961, 1963, 2000). Therefore, in a historical perspective oriented toward the reconstruction of past events, only the years during which summer rains exceeded the mean in northwestern Peru may be considered as El Niño years. River floods in central and southern Peru should not be interpreted as reliable El Niño proxies, if no corroborating evidence is also available in the coast of northern Peru. It can also be noted that in southern Peru the highest monthly precipitation (and some precipitation excess, like during the

1997 El Niño event) occurs in September-October, and thus is not directly related either with the northern Peru rainfall regime (peak of precipitation in summer) or with the early winter rainfalls of central Chile.

At another time-scale, geological records from southern Peru have been interpreted as including El Niño proxies. Several recently published papers referred to debris-flows deposits in the Ilo-Tacna coastal area (18º S) as an evidence for former El Niño events. Keefer et al. (1998) inferred from a sequence of radiocarbon-dated debris flows that El Niño manifestations were registered since the latest Pleistocene in Quebrada Tacahuay. Fontugne et al. (1999) argued from the lack of debris-flows deposits in an alluvial sequence at Quebrada Los Burros, that no El Niño events seem to have occurred between 8970 cal BP and 3380 cal BP events. These interpretations were discussed at length by Ortlieb & Vargas (in press), who provided additional observations and geochronological data on various alluvial fan sequences from southern Peru. According to the available chronological data, at least 4 major debris flows were identified along the coast of southern Peru during the second half of the Holocene. Several debris-flow and sheetflood deposits, dated between 12 730 cal BP and 8660 cal BP were also recognized in the same area (Keefer and others, 1998). Other sheetflood and debris flow units, which resemble those of the Pleistocene-Holocene boundary, had previously been deposited during (?) and after the last glacial maximum (Keefer and others, 1998). We interpret that the latest Pleistocene sequence of debris flows and sheetfloods resulted from a quite wetter climate than in the second half of the Holocene, and that these rainfalls do not necessarily relate with ENSO phenomena. In Quebrada Tacahuay, in particular, the stratigraphical sequence documents clearly that it was in the mid-Holocene (after 5290 cal BP) that occurred a drastic change in the hydrological regime, and that the quebrada began to be incised (Keefer and others, 1998). The first half of the Holocene seems to have been characterized by a relatively arid climate, without strong rainfalls, but with enough humidity to maintain some grass vegetation in the major quebradas.

Even if several strong rainfalls (able to generate debris flows) were coeval with recent ENSO events, it is concluded that many (strong or very strong) El Niño events do not produce rainfall excess in southern Peru. Anomalous rainfalls may also occur during La Niña events. At another time scale, it is interpreted that debris-flow deposits which were formed prior to the mid-Holocene and in the latest Pleistocene may not be linked to ENSO conditions (either El Niño or La Niña phases), and rather reflect other climatic patterns.

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